EXPLORATIONS IN ECONOMIC HISTORY **33,** 479–495 (1996)
ARTICLE NO. 0026

"Imaginary" or "Real" Moneys of Account in Medieval Europe? An Econometric Analysis of the Basle Pound, 1365–1429*

ERNST JUERG WEBER

Department of Economics, University of Western Australia

During the Middle Ages, the medium of exchange function of money was separate from the unit of account function. This has given rise to the misconception that the medieval pound was an "abstract" or "imaginary" unit of account whose purchasing power was independent of that of gold and silver coins. The joint behavior of the pound price of gold, the pound price of silver, and the silver–gold ratio in Basle between 1365 and 1429 cannot be reconciled with the notion that nominal values were autonomous. Instead, the monetary system was based on a silver standard, supplemented by gold coins whose money of account values were determined by this silver standard.

I. INTRODUCTION

The economic history literature presents two, quite radically different approaches to the subject of medieval moneys and moneys of account. Many, and perhaps most, economic historians believe that each money of account was somehow—either through habit or some official decree—tied to a specific coin, even if it may now be difficult to establish precisely which one. In western Europe, from Carolingian times to the French Revolution (from 795 to 1789), the most widely used money of account was based on the pound, originally what was thought to have been the old Roman pound weight (libra) of silver. Although each medieval "pound" money of account differed in value from all others, almost all such pounds were subdivided into 20 shillings (sous, solidi, schelling); and each shilling into 12 pence (deniers, denarii), so that each pound consisted, and always consisted, of 240 pence.[1] Accordingly, the pound, with these subdivisions, was a "real" unit of account whose purchasing power depended on the amount of precious metal in the "link" coin, the one on which the money of account was based, usually the penny; for indeed for several centuries up to ca. 1200 most

* I thank Ken Clements and the participants in a seminar at the University of Western Australia for helpful comments.

[1] The pound units of cities and principalities were indepenent currency units. Spufford (1988, pp. 291–299) records 26 principal pound moneys of account in western Europe.

0014-4983/96 $18.00

medieval princes or states minted only pennies and their subdivisions (half and quarter pence).

The alternative approach holds—a view still strongly held to this day—that the pound was an imaginary or abstract unit of account that was independent of any coin. The most prominent advocate of this view was the Italian economist Luigi Einaudi, who insisted that all medieval coins were a commodity like any other whose pound price was determined by market forces. Einaudi (1936/1953, pp. 257) argued, ''. . . because of the existence of money of account, men every day set a [pound] price on the florins, scudi, écus, doublons, sequins, and testoons which they received and paid out. Every day, in every single transaction, it was made clear to their minds that the money which they paid, even bank money or paper money, was a commodity like any other . . .'' In an essay in honor of Irving Fisher's 75th birthday, Einaudi (1937, p. 261) referred to Galiani (1750) who asked, ''Why should the state fix the [pound] price of coins? The prices of wheat, wine and oil are much more important than the price of coins; and no statute but only the common opinion of the people regulate them.'' But like Galiani, Einaudi then ''bows to the prejudices of mankind,'' accepting that the government should fix the pound price of some foundation or link coin in order to secure a nominal anchor.[2]

The political fragmentation of medieval Europe accounted for the vast number of autonomous mints. Numerous sorts of coins, issued by secular and ecclesiastical bodies, circulated along European trade routes. In cities and at fairs, the media of exchange consisted of scores of gold and silver coins and an unknown quantity of billon or ''black'' moneys whose silver content was minimal, usually well under 25%, so that their predominantly base-metal (copper) composition gave them a black appearance.[3] Exchange rates between coins depended on their metal weight and prevailing metal prices. The degradation of some gold coins and high-value silver coins, through wear and tear, and especially through deliberate clipping and ''sweating,'' often made it necessary for merchants to value them individually, as bullion, through touchstones and weighing scales; but the transaction costs involved in doing so for low-value silver and billion coins were usually prohibitive, so that such coins normally circulated by ''tale'' (counting), i.e., by assigned official values.

The use of medieval coins as means of payment involved substantial transaction (accounting) costs that were mitigated by a common unit of account. Commodity prices were quoted in pound money of account and payments were made in an assortment of coins whose values were also expressed in pound money of account. So, what determined the purchasing power of the pound money of

[2] Van Werveke (1934) and de Roover (1948, pp 220/221) questioned Einaudi's concept of imaginary money. Cipolla (1956, Chaps. 4 and 5) discussed ''ghost moneys'' in southern Europe. Lane and Mueller (1985, Chap. 20) review the positions of economic historians on medieval pound moneys of account. Spufford (1988, Appendix II) rejects the notion of imaginary money.

[3] Munro (1988) discusses coinage debasements and moneys of account in Flanders between 1334 and 1484.

account? The difficulty is that it is usually not possible to establish a clear-cut relationship between the pound and a specific brand of coins. Medieval coins did not carry a face value in terms of pound money of account. Usually, there were no coins with a metal value of exactly one pound or some obvious multiple or fraction of it. When mints issued full-valued shillings or pennies, their value in terms of pound money of account quickly diverged from parity.

The medieval pound system sheds light on a recent strand of monetary research that deals with laissez-faire monetary systems. Hayek (1976/1978) proposed that currencies should be issued privately in order to achieve price stability. During the past decade, many authors contributed to this research and it is now clear that media of exchange can be issued privately if an official unit of account already exists. In fact, bank notes were issued privately in many countries during the gold standard in the 19th century.[4] However, the nature of the unit of account remains a mystery if—as proposed by Hayek—the government does not define an official currency unit. Cowen and Kroszner (1992) suggest that an abstract money of account may evolve. But the notion of an abstract unit of account is rejected by others who argue that information costs encourage a link between the unit of account and the medium of exchange. The nature of the unit of account or nominal anchor plays a central role in modern monetary economics because rapid advances in payments technology undermine the quantity theory by rendering holdings of media of exchange unnecessary.[5]

The next section outlines Basle's political history during the late Middle Ages. This section provides the background for the monetary analysis that follows in Sections 3 and 4 because political events determined the course of monetary policy.

2. BASLE

During the Middle Ages, Basle belonged to a group of medium-sized cities in southern Germany that were administered by nobles and Church bodies within the loosely structured Holy Roman Empire. The city was well positioned along the trade routes that led from northern Italy through the Swiss Alps to Flanders and the Hanseatic cities in northern Germany.[6]

In the second half of the 14th century, the citizens gradually wrested control from the nobility and the Church through diplomacy and warfare. The political conflict involved shifting alliances between five parties—the citizens, the Bishop,

[4] McCallum (1985), and Selgin and White (1994) review the literature on competitive monetary systems. Cowen and Kroszner (1992, 1987) and Sumner (1990) add the work of precursors. Weber (1992, 1988) deals with the private issue of bank notes in Switzerland.

[5] *The Economist* (November 26, 1994, pp. 23–27) recently suggested that an abstract money may evolve on the Internet.

[6] Between 1350 and 1450, Europe experienced a severe economic and social crisis. The plague struck in the region of Basle for the first time in 1348/1349. Overall, the plague and wars reduced Europe's population by about one third. On top of that, Basle was devastated by an earthquake and fire in 1356.

the minor nobility, the Duke Leopold III of Austria, and the Swiss League. The citizens were organized in the trade guilds. In the 1360s, Basle sided with Austria against the nobility in southern Germany. However, the city's growing economic and political power interfered with Austrian interests in the region. By 1374 the trade guilds dominated the city council, the nobility was banned, and aristocratic strongholds were destroyed in the countryside. In 1375 the Duke of Austria and the Bishop jointly besieged the city, restoring the artistocratic order. But the Austrian regime did not last long and representatives of the trade guilds were readmitted to the city council in 1382. Two years later, Basle joined the Union of Southern German Cities (schwäbischer Städtebund), which was an alliance against Austria. In 1386 the Swiss routed the Austrians in the battle at Sempach, imposing a heavy toll on the nobility and killing Duke Leopold III. Sempach marks the end of the influence of the House of Habsburg in the domain of Switzerland.[7]

At the end of the 14th century, a new aristocracy emerged. The city council, which had challenged the feudal system a generation earlier, became self-appointed and the trade guilds embraced protectionism. The new aristocracy survived until the French Revolution. During the 15th century, Basle became an important commercial and political center in central Europe. A Church Council met within its walls from 1431 to 1448.[8] The Council was the second in a row of three that were motivated by the so-called Concilar Movement—the first was held in Constance to the east of Basle from 1414 to 1418, and the third followed in Ferrara and Florence. In 1433–1434 the German emperor Sigismund participated in the Council. The city's population temporarily increased from between 8,000 to 10,000 before the Council to about 12,000 when it was most active.

3. MONETARY SYSTEM

As in other medieval cities, the monetary system of Basle consisted of a local pound unit and a heterogeneous coinage, which had been acquired through trade. In the 14th century, the use of gold coins, minted from increased supplies of this metal mined in Hungary and obtained by Italian commerce with North Africa, spread throughout western Europe. In Basle popular gold coins included the florin and ducats from northern Italy and the German rhinegulden. The price of gold in terms of pound denotes the exchange rate because gold provided the interregional medium of exchange. The monetary authority—the Bishop during the feudal period and the city council afterward—controlled the silver weight of the penny.[9] This suggests that the pound was a silver unit of account with a value of 240 pennies. But a change in the silver weight of the penny only produced a corresponding change in the pound price of commodities if the new pennies were

[7] Basle joined Switzerland in 1501.

[8] This includes the period after 1437 when Pope Eugen IV did not recognize the Council. In 1439 the Council installed Felix V as Antipope.

[9] In 1373 the city council bought the right of coinage from the Bishop for 4000 pounds.

traded at par. The pound was an independent unit of account to the extent that changes in the silver weight of the penny did not affect nominal values. Indeed, Einaudi explicitly rejected the view that the silver weight of the penny determined the purchasing power of pound money of account in medieval monetary systems:

> The coexistence over long periods of time of a penny in money of account and a penny in coin, one equal to the other, does not prove, as Landry (*Essai,* p. 13) rightly observes, that the two systems, that of imaginary and that of real money, were linked or soldered together. It is not correct to say that through the penny both currency systems were based on a real coin. . . . It was possible that at a given moment one silver penny was equivalent to one penny in money of account. But the relation between the [gold] mouton, the silver groat, and the silver penny was not so stable as that between the pound, the shilling, and the penny, since, in terms of money of account, a pound was always 20 shilling and one shilling was always 12 pence. Besides, even when the groat was rated 1 shilling, it does not follow that it contained twelve times as much silver as the penny. Little by little—and this happened during the fourteenth and fifteenth centuries—the penny in coin lost its equivalence with the penny in money of account and was coined first in vellon (that is, an alloy composed mainly of copper and a little silver) and then in pure copper. (Einaudi, 1936/1953, p. 234)

This quote by Einaudi misrepresents the role of the penny in the monetary system of Basle and other medieval cities. During the late Middle Ages, Basle experienced a period of moderate inflation. From 1370 to the end of the century, the pound price of both silver and gold roughly tripled, amounting to an average annual inflation rate of close to four percent (Fig. 1). The conflict between the citizens and the nobility determined the inflationary process. The nobility's income from land tenure, bondage, and other feudal privileges was denominated in pound money of account. Therefore, the citizens benefited from a depreciation of the pound at the cost of the nobility. Technically, the inflationary process was put into motion by a reduction in the silver weight of the penny. Figure 1 shows the official silver price that can be calculated from the silver weight of the penny.

The tug-of-war between the citizens and the nobility explains the discrete changes in the silver price. In the early 1370s the citizens gained the upper hand. The silver weight of the penny was reduced by 24.67 percent in 1370, and by another 16.2 percent three years later. When the nobility returned to power in 1375, the pound was revalued by 38.25%. After the defeat of the nobility in the battle at Sempach, the city council resumed devaluing the pound. Finally, the new aristocracy that emerged toward the end of the century had economic interests similar to the old nobility. The silver weight of the penny again rose at the expense of those who had to make nominally fixed payments, leading to riots in 1401/02. In 1403, Basle concluded a monetary union with cities in southern Germany and Switzerland—the so-called *Rappenmünzenbund*—that involved a revaluation of the pound by 34%.

The inflation in Basle was not an isolated event. Contrary to popular perception, inflation was quite common in the metallic monetary standards of the Middle Ages. Spufford (1988, pp. 296–299) graphs the price of gold in terms of local pound moneys of account in a dozen cities and countries. Particularly violent

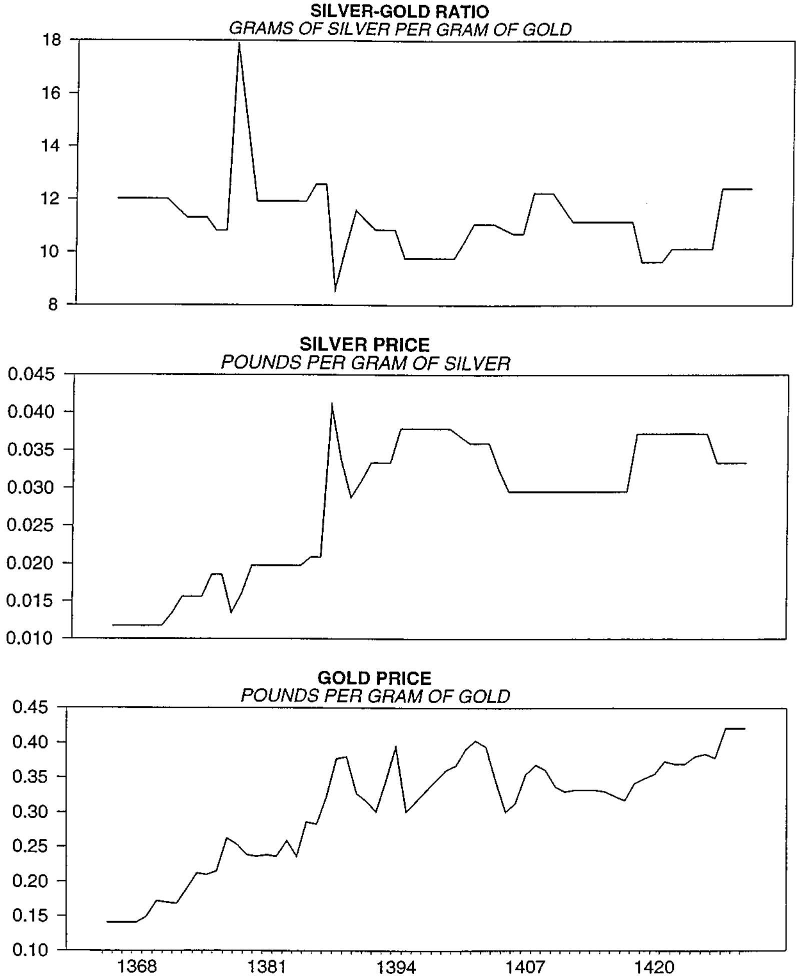

FIG. 1. Silver–gold ratio, silver price, and gold price in Basle, 1365–1429; from Rosen (1989, pp. 143–147). The data are discussed in Appendix A.

inflationary episodes—in some cases repeatedly—occurred in Bohemia, France, Flanders, Austria, Castille, and Cologne, whereas the pound units of the Italian city states, Aragon and England were quite stable. The principal motives of inflation were the seignorage motive and—as in Basle—the reallocation of wealth between social groups.[10] The inflationary process in Basle was typical of that in other places. Inflation arose when the monetary authorities lowered the precious metal content of some foundation or link coin. This was achieved by reducing the

[10] In monarchies the conflict pitted the king against the nobility. Inflation benefited the king who earned seignorage.

coin's weight and/or its fineness. In Basle the monetary authorities controlled the make of the penny.

So far, it appears that the silver weight of the penny was a policy variable that each political group exploited to its own advantage. However, this was not the only motive of monetary policy. The monetary authorities also used the silver price to shelter the gold price from autonomous changes in the silver–gold ratio.[11] The gold price was important because it provided the exchange rate. The expansion of gold mining in Hungary and the influx of gold from North Africa led to a fall in the silver–gold ratio in the second half of the 14th century (Fig. 1). This required an increase in the silver price in order to keep the gold price constant. In addition, political events induced shifts in the relative demand for silver and gold that produced short-run fluctuations in their relative price. In 1375, people shifted from silver to gold because they correctly anticipated that the official silver price would be reduced after the return of the nobility. This shift in relative demand sharply increased the silver–gold ratio in Basle. In the end, the authorities reduced the silver price—not only because this benefited the nobility—but also to neutralize the effect of the associated response in the silver–gold ratio on the gold price. But the local silver–gold ratio only temporarily deviated from that in the rest of Europe because of arbitrage. Therefore, the authorities had to readjust the silver price in 1378–1379 to keep the gold price constant. The same temporary responses—with opposite signs—occurred after Sempach in 1386.[12]

4. IMPULSE RESPONSES

Currency arbitrage implies the following equilibrium condition between the logarithms of the pound price of gold ($P_{\mathrm{g}}^{\pounds}$), the pound price of silver ($P_{\mathrm{s}}^{\pounds}$) and the silver–gold ratio ($P_{\mathrm{g}}^{\mathrm{s}}$):

$$P_{\mathrm{g}}^{\pounds} = P_{\mathrm{s}}^{\pounds} + P_{\mathrm{g}}^{\mathrm{s}}. \tag{1}$$

The right side of Eq. 1 measures the par value of gold in the foreign exchange market. It depends on the official silver price and the autonomous silver–gold ratio. The silver price was a policy variable that was controlled by the monetary authorities, and the silver–gold ratio was a relative price that depended on the demand for both metals and mining costs. Reflecting actual market conditions, the gold price deviated from parity. The equilibrium condition (1) did not hold continuously because transaction costs in currency markets prevented perfect arbitrage. These transaction costs involved the transport of gold and silver between neighboring cities—a hazardous task on medieval roads and through

[11] Harms' (1907) monetary history of Basle during the Middle Ages is still well worth reading. He emphasized the monetary authorities' attempt to stabilize the pound price of gold.

[12] It seems unlikely that these temporary changes in the official silver price involved a complete recoinage of all silver pennies. New coins circulated side by side with old ones, and legal tender laws and other monetary regulations guaranteed that the new pennies traded at par and the old pennies either at a premium or discount (depending on whether they included more or less silver than the new ones). Rolnick and Weber (1986) deal with the role of legal tender laws in metallic standards.

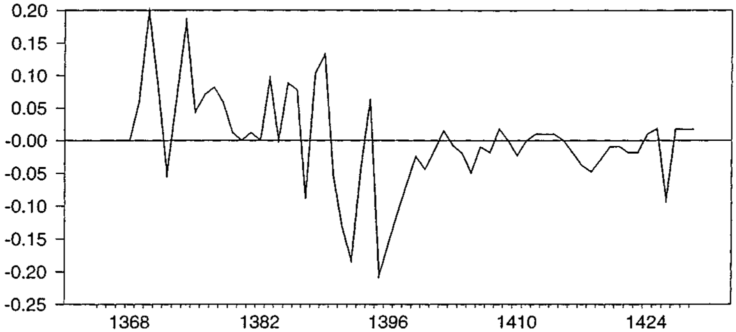

FIG. 2. Gold premium in Basle, 1365–1429.

hostile territories.[13] Thus, similar to the gold standard in the 19th century, the gold price fluctuated between upper and lower gold points, which were determined by transaction costs in currency markets.

In the early 1370s, the political turmoil induced capital flight. The public demanded foreign exchange in the form of gold coins, bidding up the pound price of gold in Basle. As a consequence, the pound depreciated and gold rose above par (Fig. 2). The gold premium ($P_g^£ - P_s^£ - P_g^s$) reached 22.0% in 1370, and 20.0% in 1374. After the restoration of the feudal order by the Austrians, the gold premium abated and gold traded close to par by the end of the decade. Then, the political conflict resumed and the pound again weakened. From 1383 to 1389, the gold premium amounted on average to 6.3%. Finally, after the ouster of the nobility, the removal of feudal trade barriers stimulated local manufacturing. This produced a trade surplus that accounted for the strong pound in the 1390s.

The following econometric analysis makes use of multivariate time series models. A vector-autoregressive model (VAR) is estimated and impulse responses are calculated that capture the joint behavior of the gold price, the silver price and the silver–gold ratio in Eq. 1.

Multivariate time series models require series that are either individually or jointly stationary. Dickey–Fuller tests show that the price of gold, the price of silver and the silver–gold ratio are all nonstationary. However, the currency arbitrage condition (1) implies a linear long-run relationship between the logarithm of all three variables. A unit root test on the gold premium confirms that it is stationary. In addition, a cointegration test on the silver–gold ratio, the silver price and the gold price indicates a long-run relationship. Thus, the interaction between these variables can be analyzed using levels instead of differences—although these variables are nonstationary. The advantage of using levels instead of

[13] European roads were not safe during the Middle Ages. One of the biggest raids occurred in 1390 when the margrave of Baden ambushed a convoy of traders that traveled to Frankfurt. Just in Basle, 60 traders declared losses of 12,000 gulden.

differences is that long-run relationships are preserved. The unit root and cointegration tests are summarized in Appendix B.

The VAR model to be estimated can be written as

$$y_t = \sum_{s=1}^{L} B_s y_{t-s} + u_t. \tag{2}$$

y_t is a 3-dimensional vector of variables that includes the silver–gold ratio, the silver price, and the gold price. B_s is a 3×3 matrix of coefficients and L indicates the number of lags. u_t is a 3-variate white noise process. Innovations may be correlated across variables within a single time period. Thus, the covariance matrix of innovations $E(u_t u_s') = \Sigma$ is nondiagonal if $t =$ s, and all elements of Σ are zero if $t \neq s$.

The estimated model (2) will be used to calculate the response in each variable to shocks to the other variables. A variable depends on another variable if it is influenced by random shocks to that variable. On the other hand, a variable is statistically exogenous if it is completely determined by its own innovations. The pound was a silver unit of account if shocks to the silver price induced a proportional response in the gold price, and shocks to the gold price did not affect the silver price. Equation (3) decomposes each variable into past innovations. The ith column of the C_s matrix indicates the responses in period t to a shock to the ith variable in period $t - s$:

$$y_t = \sum_{s=0}^{\infty} C_s u_{t-s}. \tag{3}$$

A further point concerns the contemporaneous correlation among shocks that is shown by the off-diagonal elements of Σ. Shocks are usually orthogonalized because it is misleading to assign a shock to a single variable if shocks are correlated across variables. Equation 3 can be rewritten as

$$y_t = \sum_{s=0}^{\infty} C_s G G^{-1} u_{t-s}. \tag{4}$$

G is a lower triangular matrix that provides a Choleski factorization of Σ. The new shocks $v_t = G^{-1} u_t$ are orthogonal if G is chosen so that $GG' = \Sigma$.[14] The impulse responses are calculated from unit shocks to the elements of the vector v_t. The ith column of G shows the first period effect of a unit shock to the ith element of v_t because $u_t = G v_t$. The impulse responses may depend on the ordering of variables because G is lower triangular. The ordering of variables is only important if the contemporaneous correlation between shocks is large.

Table 1 shows the estimated contemporaneous covariance matrix of innovations Σ. Variances and covariances are shown on and below the diagonal and

[14] It follows $G^{-1}\Sigma G'^{-1} = I$. Then, $E(v_t v_t') = E(G^{-1} u_t u_t' G'^{-1}) = I$.

TABLE 1
Covariance/Correlation Matrix of Residuals

	SIGO	POSI	POGO
SIGO	0.0079	−0.8553	0.2211
POSI	−0.0082	0.0115	0.1061
POGO	0.0013	0.0008	0.0044

Note. Variances and covariances are shown on and below the diagonal, and correlation coefficients on top.

correlations coefficients on top. Shocks to the silver–gold ratio and the silver price were strongly negatively correlated with a correlation coefficient of −0.86. All other correlations between shocks were small. Thus, the ordering of the silver–gold ratio and the silver price matters in the Choleski factorization. The complete ordering of variables is silver–gold ratio, silver price, and gold price. The silver–gold ratio is ordered first because it is a relative price that is independent of nominal prices. The silver price is put second because it was managed by the monetary authorities, and the gold price is last because it was endogenously determined in the foreign exchange market.

Figure 3 shows the impulse responses from the estimated VAR model, along with two-standard-deviation error bands.[15] The first column contains the response in the silver–gold ratio to own shocks (panel 1.1) and to shocks to the silver price (panel 2.1) and gold price (panel 3.1). Similarly, the second and third column present the responses in the silver price and gold price. The impulse responses cover 12 years. The vertical axis measures percentage changes because all variables are logarithmic. Within a column, the vertical axis of each panel has the same range to facilitate a comparison of the relative importance of shocks on a single variable.

These recorded impulse responses shed new light on the nature of the medieval monetary system in Basle and thus upon so many closely related money of account systems to be found throughout late-medieval Europe.

4.1. The pound was a silver unit of account. Autonomous changes in the silver price permanently affected the value of the pound. An orthogonalized unit shock to the silver price increased both the silver price and gold price by about 2.5% in the long-run (Fig. 3, panels 2.2 and 2.3). The pound was a silver unit of account because changes in the silver weight of the penny had a persistent effect on both the silver price and gold price, and shocks to the gold price did not affect the silver price (panel 3.2). The silver price had a strong effect on nominal values. Shocks to

[15] The sample period lasts from 1370 to 1429. The Akaike information criterion suggests a model with two lags. LM tests indicate that serial correlation is no problem. The confidence intervals were calculated by the Bayesian Monte Carlo integration that is described in the RATS 4 manual (p. 10-5). The estimated model is included in a working paper that is available from the author.

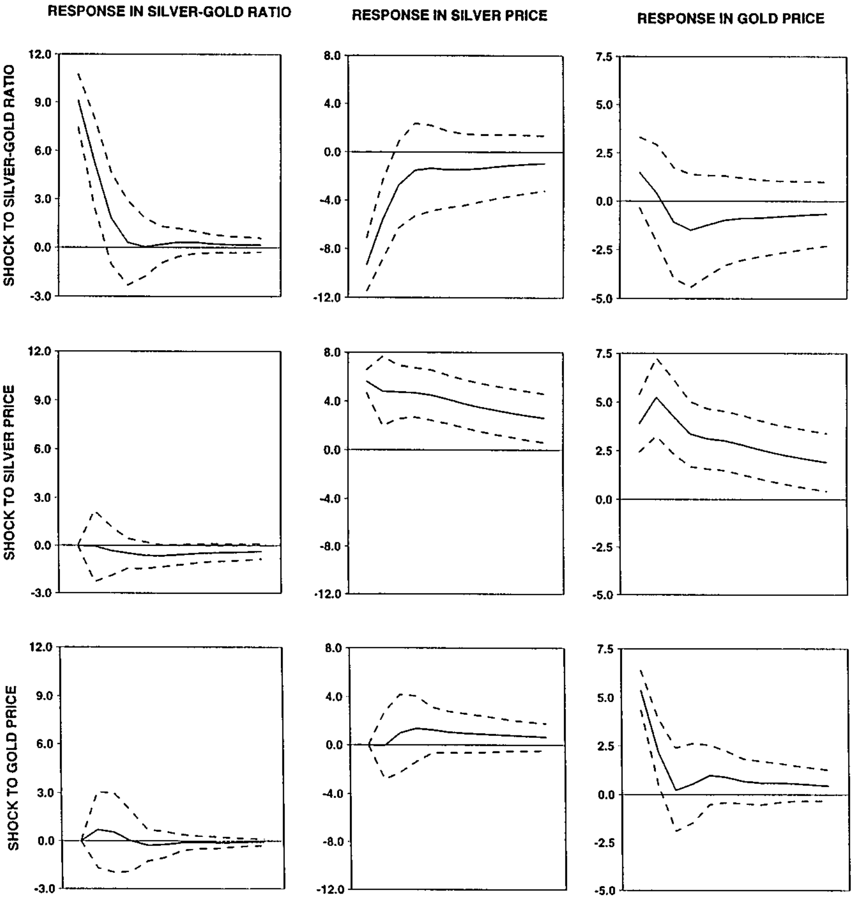

FIG. 3. Impulse responses.

the silver price explain almost all of the total variability of the silver price and gold price in the long-run (columns 2 and 3).

4.2. The gold price was the exchange rate. Shocks to the gold price dissipated within three years (Fig. 3, panel 3.3), and they did not influence the silver price (panel 3.2). Thus, shocks to the gold price did not affect nominal values in the long-run. This pattern is typical for the exchange rate in a metallic standard. The product of the silver price and the silver–gold ratio determined the par value of gold in the foreign exchange market. The silver price was a policy variable and the silver–gold ratio was an autonomous relative price. Trade and capital flows produced short-run deviations of the gold price from parity. The upper and lower gold points were determined by transactions costs in currency markets.

4.3. Monetary policy was independent. Shocks to the silver–gold ratio must coincide with a change in the price of at least one metal. The impulse responses

show that changes in the silver–gold ratio mostly influenced the silver price (Fig. 3, panel 1.2) and to a lesser extent the gold price (panel 1.3). This was the outcome of deliberate monetary policy. The monetary authorities used the silver price to shelter the gold price from shocks to the silver–gold ratio. They exploited the silver price in order to stabilize the exchange rate. As a consequence, the gold price and other nominal values were invariant to changes in the silver–gold ratio.

4.4. The silver–gold ratio was a relative price. Shocks to both the silver price and gold price did not affect the silver–gold ratio (Fig. 3, panels 2.1 and 3.1). In addition, shocks to the silver–gold ratio were purely temporary (panel 1.1). Political events induced substitution between silver and gold affecting their relative price in Basle. Arbitrage guaranteed that the silver–gold ratio quickly returned to the level prevailing elsewhere in Europe.

5. CONCLUSION

During the Middle Ages, the medium of exchange function of money was separate from the unit of account function. Commodity prices were quoted in money of account and payments were made in coins whose values were also expressed in money of account. This has produced much confusion among medievalists. Einaudi suggested that the pound was an abstract unit of account. The notion of an abstract unit of account has a long tradition in monetary economics and it has recently resurfaced in the literature on laissez-faire monetary systems. This paper has demonstrated that the separation of the unit of account from the media of exchange did not produce an abstract unit of account in Basle. Instead, the monetary history of Basle supports the view that the pound was always related to some real coin. In Basle the foundation or link coin was indeed the silver penny.

Why did Einaudi insist that the medieval pound unit was an abstract unit of account? His research concerned the monetary systems of Italian city states whose pound units—together with those of Aragon and England—provided the most stable currency units during the Middle Ages. It is difficult to reject Einaudi's view in a situation with no inflation. The strong correlation between the silver–gold ratio and the silver price could either be attributed to deliberate monetary policy in order to stabilize the exchange rate, or it could be understood as a necessary response in the silver price because at least one metal price must adjust if the silver–gold ratio changes. The issue of monetary policy independence lies at the heart of modern monetary economics.[16] Einaudi dismissed the effect of deliberate changes in the metal weight of coins on nominal values because it posed no problem in the stable monetary systems of the Italian city states. Except for a slow secular upward movement, the price level did not change much for

[16] In their ''Monetary History of the United States,'' Friedman and Schwartz (1963) argued that the Federal Reserve could always have dampened fluctuations in nominal income. For a discussion of Friedman and Schwartz's concept of monetary policy independence see Lucas (1994).

centuries. Thus, inflationary expectations must have been virtually nonexistent.[17] However, Einaudi went too far when he concluded that changes in the metal weight of coins only affected their price in money of account. The inflation in Basle—and the inflationary episodes that are reported by Spufford—confirm that medieval monetary authorities had the power to conduct independent monetary policy through changes in the metal weight of some link coin. The motives of inflation included seignorage and redistribution of wealth between social groups. The autonomous shocks to the silver price and the lagged response in the gold price cannot be reconciled with the view that nominal values were autonomous. For all these reasons, we must conclude that the monetary system of Basle, so very typical of those found in late-medieval Europe, was one based essentially on a silver standard, supplemented by gold coins whose exchange or money of account values were determined by this silver standard, or more precisely by the relationships now revealed by this econometric analysis.

APPENDIX A: DATA SOURCES

In 1356 an earthquake and fire destroyed the communal archives of the city of Basle. Afterward, the city established new archives. The original documents were first edited by E. Dürr of the City Archives (Staatsarchiv) and published by B. Harms in 1909–1913. J. Rosen made this material more accessible by classifying budget items, and publishing time series on different expenditure and revenue groups. For this purpose, he processed close to 60,000 transactions, covering the years from 1360 to 1535. This work was done in the 1970s on the computers of the Federal Institute of Technology in Zürich, the cantonal administration of Basel-Stadt, and the pharmaceutical company Sandoz. The Swiss National Fund and the Canton of Basel-Stadt provided financial support. Rosen (1989) collects the author's publications that appeared in Swiss and German journals of economic history between 1971 and 1987.

The price series that are used in this article (Fig. 1) are a by-product of Rosen's work on the city budget. The city books were kept in pound money of account. Besides the value in terms of pound ($P^{£}_{\mathrm{x}}$), the books showed the actual amount of pennies that was either received or paid (P^{p}_{x}), and often the equivalent amount of gold in the form of rhinegulden (P^{r}_{x}). The subscript x stands for a particular budget item. The pound price of gold ($P^{£}_{\mathrm{g}}$) was calculated by dividing the price in terms of pound money of account ($P^{£}_{\mathrm{x}}$) by both the price in terms of rhinegulden (P^{r}_{x}) and the known gold weight of the rhinegulden ($P^{\mathrm{g}}_{\mathrm{r}}$). This is in logarithmic form:

$$P^{£}_{\mathrm{g}} = P^{£}_{x} - P^{\mathrm{r}}_{x} - P^{\mathrm{g}}_{\mathrm{r}}. \tag{A1}$$

The silver–gold ratio ($P^{\mathrm{s}}_{\mathrm{g}}$) was calculated from the actual amount of silver and gold that was used in a transaction. The penny price (P^{p}_{x}) was multiplied with the silver weight of the penny ($P^{\mathrm{s}}_{\mathrm{p}}$) to derive the price in terms of physical silver. This

[17] Harms (1907, p. 220) believed that there was only a weak link between pound money of account and the penny in Basle before the inflation in the second half of the 14th century.

is the first bracket in Eq. A2. Similarly, the rhinegulden price (P_x^{r}) and the gold weight of the rhinegulden ($P_{\mathrm{r}}^{\mathrm{g}}$) yielded the price in terms of physical gold. The silver–gold ratio was calculated by dividing the price in terms of physical silver by the price in terms of gold. In logarithmic form:

$$P_{\mathrm{g}}^{\mathrm{s}} = (P_x^{\mathrm{p}} + P_{\mathrm{p}}^{\mathrm{s}}) - (P_x^{\mathrm{r}} + P_{\mathrm{r}}^{\mathrm{g}}). \tag{A2}$$

The pound price of silver ($P_{\mathrm{s}}^{\pounds}$) is the official silver price that can be derived from the silver weight of the penny ($P_{\mathrm{p}}^{\mathrm{s}}$):

$$P_{\mathrm{s}}^{\pounds} = -P_{\mathrm{p}}^{\mathrm{s}} - \ln 240. \tag{A3}$$

Equation 1 in the main text uses the pound price of gold, the silver–gold ratio, and the pound price of silver from Eqs. (A1) to (A3). The equation is no identity because the left-hand side and the right-hand side were calculated independently. It should be noted that all terms cancel out if the definitions from Eqs. A1 to A3 are substituted into Eq. 1, except for the price in terms of pound money of account ($P_x^{\pounds}$) that remains on the left, and the price in terms of penny (P_x^{p}) on the right. Thus, the gold premium ($P_{\mathrm{g}}^{\pounds} - P_g^s - P_{\mathrm{s}}^{\pounds}$) measures the deviation between the purchasing power of pound money of account and that of the underlying penny. It is natural to associate the price of gold in terms of pound money of account with the exchange rate because it was derived from the rhinegulden price of a budget item. The rhinegulden was the most popular gold coin in foreign transactions.

APPENDIX B: TIME SERIES PROPERTIES

1. Unit Root Tests

The tests cover the period from 1370 to 1429. All data are in logarithmic form (see Table 2).

The silver–gold ratio (SIGO) is tested for $(a, c) = (0, 1)$ in

$$y(t) = a + cy(t - 1) + e(t)$$

or

$$y(t) - y(t - 1) = a + (c - 1)y(t - 1) + e(t).$$

With 50 observations, the critical value of the F-statistic is 4.71 at the 5% level (Dickey and Fuller 1981, Table IV, p. 1063). There were two lagged dependent

TABLE 2

Variable	F/t-Statistic
SIGO	3.71
POSI	3.30
POGO	5.37
PREM	2.19

TABLE 3

	SIGO	POSI	POGO	PREM
Intercept (a)	0.900	−0.390	−0.281	
	(2.72)	(−1.37)	(−2.65)	
Trend (t)		0.000	0.002	
		(0.11)	(1.77)	
$y(t-1)$	−0.373	−0.114	−0.207	−0.342
	(−2.72)	(−1.66)	(−3.06)	(−2.19)
$dy(t-1)$	0.026	−0.150		−0.223
	(0.18)	(−1.17)		(−1.25)
$dy(t-2)$	−0.202	−0.291		−0.507
	(−1.53)	(−2.30)		(−3.00)
$dy(t-3)$				−0.089
				(−0.51)
$dy(t-4)$				−0.154
				(−1.10)
$dy(t-5)$				0.220
				(1.73)
Q	13.21	14.94	8.89	5.73
LM1	0.01	0.22	0.05	0.67
LM2	0.06	0.24	1.91	0.93
LM3	0.08	0.38	2.39	1.84
LM4	0.40	0.61	2.53	2.47
LM5	0.52	1.11	2.36	2.98

Note. The parentheses show t-values.

variables added to remove serial correlation. The null hypothesis that the silver–gold ratio follows a random walk cannot be rejected.

Both the silver price (POSI) and gold price (POGO) were tested for $(a, b, c) = (a, 0, 1)$ in

$$y(t) - y(t-1) = a + bt + (c-1)y(t-1) + e(t).$$

With 50 observations, the critical value of the F-statistics is 6.73 at the 5% level (Dickey and Fuller 1981, Table VI, p. 1063). The silver price required two lags and the gold price none. The null hypothesis that both series follow a random walk with drift cannot be rejected.

The gold premium was tested for $c = 1$ in

$$y(t) - y(t-1) = (c-1)y(t-1) + e(t).$$

With 50 observations, the critical value of the t-statistic is 1.95 at the 5% level (Fuller 1976, Table 8.5.2, p. 373). There were five lags added to remove serial correlation. The null hypothesis that the series follows a random walk is rejected.

The estimated equations are shown in Table 3.

TABLE 4

	SIGO	POSI	POGO
	Cointegration regressions		
SIGO		−1.241	1.055
		[0.079]	[0.089]
POSI	−0.651		0.881
	[0.042]		[0.029]
POGO	0.670	1.067	
	[0.056]	[0.035]	
Constant	0.864	0.659	−0.561
	[0.094]	[0.184]	[0.170]
	Unit root tests on residuals		
Res	−0.860	−0.950	−0.991
	(−5.69)	(−6.17)	(−6.21)
DRes	0.190	0.222	0.24
	(1.51)	(1.80)	(1.99)

Note. The brackets show standard errors and the parentheses show *t*-values.

2. Cointegration Tests

There exists a long-run relationship between a group of time series if regressing one series on the others yields stationary residuals. Since there are three series, there are three possible cointegration regressions. A modified Dickey–Fuller test was applied to the residuals. With 50 observations and three variables, the critical value lies between −4.84 (no lags) and −4.45 (four lags) at the 1% level (Engle and Yoo 1987, Tables 2 and 3). The Akaike information criterion suggests one lag for all regressions on the residuals. The null hypothesis that the residuals are nonstationary is always rejected (see Table 4).

REFERENCES

Cipolla, C. (1956), *Money, Prices, and Civilization in the Mediterranean World.* Princeton, NJ: Princeton Univ. Press.

Cowen, T. and Kroszner, R. (1992), ‘‘German-Language Precursors of the New Monetary Economics.’’ *Journal of Institutional and Theoretical Economics* **148,** 387–410.

Cowen, T. and Kroszner, R. (1987), ‘‘The Development of the New Monetary Economics.’’ *Journal of Political Economy* **95,** 567–90.

De Roover, R. (1948), *Money, Banking, and Credit in Medieval Bruges: Italian Merchant-Bankers, Lombards, and Money Changers.* Cambridge, MA: Medieval Academy of America.

Dickey, D. A., and Fuller, W. A. (1981), ‘‘Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root.’’ *Econometrica* **49,** 1057–1072.

Einaudi, L. (1953), ‘‘The Theory of Imaginary Money from Charlemagne to the French Revolution.’’ In F. C. Lane and J. C. Riemersma (Eds.), *Enterprise and Secular Change.* London: Allen and Unwin. (Teoria della moneta immaginaria nel tempo da Carlomagno all rivoluzione francese, *Rivista di storia economica,* 1936.)

Einaudi, L. (1937), ‘‘The Medieval Practice of Managed Currencies.’’ In A. D. Gayer (Ed.), *The Lessons of Monetary Experience, Essays in Honor of Irving Fisher.* London: Allen & Unwin.

Engle, R. F., and Yoo, B. S. (1987), ‘‘Forecasting and Testing in Cointegrated Systems.’’ *Journal of Econometrics* **35,** 143–159.

Friedman, M., and Schwartz, A. J. (1963), *A Monetary History of the United States, 1867–1960.* Princeton, NJ: Princeton Univ. Press.

Fuller, W. A. (1976), *Introduction to Statistical Time Series.* New York: Wiley.

Galiani, F. (1750), *Della moneta.*

Harms, B. (1907), Münz- und Geldpolitik der Stadt Basel im Mittelalter, *Zeitschrift für die gesamte Staatswissenschaft,* Ergänzungsheft XXIII.

Harms, B. (1909–1913), *Der Stadthaushalt Basels im ausgehenden Mittelalter. Die Jahresrechnungen 1360–1535.* Bd. I–III, Tübingen.

Hayek, F. A. (1976/1978), *Denationalisation of Money.* London: The Institute of Economic Affairs.

Landry, A. (1910), *Essai économique sur les mutations des monnaies dans l'ancienne France de Philippe le Bel à Charles VII.* Paris.

Lane, F. C., and Mueller, R. C. (1985), *Money and Banking in Medieval and Renaissance Venice, Coins and Moneys of Account,* Vol. 1. Baltimore: Johns Hopkins Press.

Lucas, R. E. (1994), ‘‘Review of Milton Friedman and Anna J. Schwartz's ‘A Monetary History of the United States.’’’ *Journal of Meontary Economics* **34,** 5–16.

McCallum, B. (1985), ‘‘Bank Deregulation, Accounting Systems of Exchange, and the Unit of Account: A Critical Review.’’ *The New Monetary Economics, Fiscal Issues and Unemployment.* Carnegie–Rochester Series on Public Policy **23,** 13–45.

Munro, J. H. (1988), ‘‘Deflation and the Petty Coinage Problem in the Late-Medieval Economy: The Case of Flanders, 1334–1484.’’ *Explorations in Economic History* **25,** 387–423.

Rolnick, A. J., and Weber, W. E. (1986), ‘‘Gresham's Law or Gresham's Fallacy?’’ *Journal of Political Economy* **94,** 185–199.

Rosen, J. (1989), *Finanzgeschichte Basels im späten Mittelalter.* Stuttgart: Franz Steiner Verlag.

Selgin, G. A., and White, L. H. (1994). ‘‘How Would the Invisible Hand Handle Money?’’ *Journal of Economic Literature* **32,** 1718–1749.

Spufford, P. (1988), *Money and Its Use in Medieval Europe,* Cambridge: Cambridge Univ. Press.

Sumner, S. (1990), ‘‘The Forerunners of ‘New Monetary Economics’: Proposals to Stabilize the Unit of Account.’’ *Journal of Money, Credit, and Banking* **22,** 109–118.

Van Werveke, H. (1934), ‘‘Monnaie de compte et monnaie réelle.’’ Revue belge de philologie et d'historie **13,** 123–52 (Reprinted in Van Werveke, H. (1968), *Miscellanea Mediaevalia.* Ghent).

Weber, E. J. (1988). ‘‘Currency Competition in Switzerland.’’ *Kyklos* **41,** 459–478.

Weber, E. J. (1992), ‘‘Free Banking in Switzerland after the Liberal Revolutions in the 19th Century.’’ In K. Dowd (Ed.), *The Experience of Free Banking.* London: Routledge. Pp. 187–205.